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CONTINUUM STUDIES USING HAYSTACK ANTENNA]
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SEMIANNUAL REPORT
OF THE
HAYSTACK OBSERVATORY

NORTHEAST RADIO OBSERVATORY CORPORATION

15 January 1973

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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Radar studies of the moon have been conducted under Contract NAS 9-7830 between MIT and NASA Manned Spacecraft Center, Houston, Texas. This contract terminated 31 December 1972.

Development of VLBI techniques for geodetic measurements is supported under ARPA-funded Contract Number F 23601-71-C-0092 Mod 2, between NEROC and the Aeronautical Chart and Information Center, U. S. Air Force.

Incremental support of radar studies of distant satellites is provided by MIT Lincoln Laboratory.

FOREWORD

These reports are intended to summarize typical work at Haystack for the benefit of (a) the NEROC officers and Board of Trustees (b) sponsors, particularly those to whom formal reporting is a contractual obligation, and (c) interested members of the scientific community. They also present engineering developments and other activities of interest which might otherwise not be published.

Suggestions from readers for improvement of these reports are welcome.

Paul B. Sebring

ABSTRACT

During the last half of 1972, the Haystack antenna was utilized 88% of the time. Of this useful time, 81% was devoted to radio astronomy investigations, 8% was spent on radar-related research and 11% was scheduled for maintenance and system improvements.

Thirteen programs were completed of which 10 were spectral-line studies involving primarily recombination lines and H_2O vapor investigations. The others involved 2 cm. and 1.3 cm. continuum observations.

Fifteen new programs have been accepted and the currently active radio observing programs totalled 24 as of 31 December 1973. VLBI projects continue as an exciting major area of activity at Haystack.

Progress on the development of a K-band maser for use in H_2O vapor and NH_3 spectral line research has been such that an announcement of the new instrument in a letter to Science has been possible.

The last radar measurements in the lunar topography program have now been completed. Radar activity, including measurements on Mercury, Venus and synchronous satellites has continued at a modest level.

NORTHEAST RADIO OBSERVATORY CORPORATION

A nonprofit corporation of educational and research institutions formed in June 1967 to continue the planning initiated by the Cambridge Radio Observatory Committee for an advanced radio and radar research facility. In March 1969, by agreement with MIT and Lincoln Laboratory, its interest was extended to the existing Haystack Research Facility to seek means of increasing its availability for research. Since July 1970, NEROC has directed the research at Haystack and has had the primary role in arranging for support.

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Brandeis University
Brown University
Dartmouth College
Harvard University
Massachusetts Institute of Technology
Polytechnic Institute of Brooklyn
Smithsonian Astrophysical Observatory
State University of New York at Buffalo
State University of New York at Stony Brook
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NORTHEAST RADIO OBSERVATORY CORPORATION

SEMIANNUAL REPORT

OF THE

HAYSTACK OBSERVATORY

I. INTRODUCTION AND SUMMARY

Utilization of the antenna and associated equipment may be summarized as follows:

<u>USE</u>	<u>HOURS</u>
Radio Astronomy	3095
Planetary & Lunar Radar Studies	138
Radar Observations of Synchronous Satellites	<u>175</u>
Total Scientific Use	
Maintenance & Instrumentation Improvements	<u>422</u>
TOTAL	3830
Unused	<u>538</u>
Total Hours in 1/2-Year	4368

Fifteen new radio observing programs were approved, while 13 were completed. Data concerning these and other continuing programs are given in Tables I and II.

Very Long Baseline Interferometry continues as a leading activity at Haystack. Spectral-line investigations tend to dominate the single antenna activity, as in the past. The observing phase of the topographic radar studies of the moon (HAYMOON) has now concluded, and NASA Contract NAS9-7830 with Manned Spacecraft Center, Houston, has been terminated. Data continue to be analyzed, however, under a subcontract with Jet Propulsion Laboratory, which calls for inter-comparison of radar, photographic and IR data on the lunar surface. Investigators from JPL and Boeing Aircraft are also participating in the analysis of these results.

In instrument development, the K-band helium-cooled maser, under construction at Haystack and University of Massachusetts, reached bench test with promising initial results. It is planned to begin system tests with this unit on the antenna in February 1973. Construction of a second similar unit has been started. It will be used at Itapetinga Observatory, Sao Paulo, Brazil, under an international program funded by NSF and the Brazilian government.

Design of the 1000-channel digital correlator is progressing well. Digital control and display machines for this system have been procured. We estimate that about one more year will be required to place this machine on-line for regular use.

A new Radio Astronomy Operations section has been organized with Dr. M. L. Meeks as Chief, and a Radiometers section has been similarly established under Mr. J. C. Carter. These two sections will collaborate in support of all radio observing programs at Haystack, including training activities for observing and maintenance personnel, trouble calls during observing programs, development, installation, checkout and documentation of new radio astronomy setups, and other related activities.

P.B. Sebring

TABLE 1

NEW PROGRAMS THIS PERIOD

1 July - 31 December 1972

PROGRAM	INVESTIGATORS	INSTITUTIONS	HRS. REQUESTED	HRS. USED THIS YR.	DESIGNATION
8.3-GHz Search for Recombination Line H 92α Toward 3C391	A.K. Dupree, J.H. Black E.J. Chaisson	Harvard College Obs. Smithsonian Astroph. Obs.	20	25 Complete	DUPREE-3
8.006- and 8.315-GHz Observations of H 92α and H117 β in NGC 7538	C.J. Lada E.J. Chaisson	Harvard College Obs. Smithsonian Astroph. Obs.	36	73	LADA-1
20.0- to 25.0-GHz Further Search for New Methanol Transitions	A.H. Barrett, R. Martin P. Myers	Mass. Inst. of Tech.	120	66	BARRETT-10XX
8.3-GHz Observations of 92α Recombi- nation Lines Toward S 264	J.H. Black, A.K. Dupree E.J. Chaisson	Harvard College Obs. Smithsonian Astroph. Obs.	20	32	BLACK-1
22-GHz Search for H $_2$ O Emission from Certain HII Regions	B.F. Burke, K.Y. Lo	Mass. Inst. of Tech.	48	68	BURKE-5
7.76-GHz Search for OH Emissions from the J = 3/2, π_1 State	D.F. Dickinson	Smithsonian Astroph. Obs.	20	11	DICKINSON-9
7.9-GHz Continuum Mapping of HII Regions with Large IR Excess	L.E. Goad	Harvard College Obs.	54	77	GOAD-3
22-GHz Monitoring & Polarization Measurements of H $_2$ O Sources	K. Bechis, A.H. Barrett	Mass. Inst. of Tech.	200	129	BECHIS-1
8.3-GHz Observations of 92α Recombination Lines to Measure the He/H Ratio	E. J. Chaisson	Smithsonian Astroph. Obs.	104	38	CHAISSON-13
8- and 15.5-GHz Continuum Observa- tions of Symmetric Nebulae	H.M. Johnson	Lockheed, Palo Alto Research Lab.	150	0	JOHNSON-2

TABLE 1 (Cont'd)

Page 2

NEW PROGRAMS THIS PERIOD

1 July - 31 December 1972

PROGRAM	INVESTIGATORS	INSTITUTIONS	HRS. REQUESTED	HRS. USED THIS YR.	DESIGNATION
20.2- and 20.4-GHz Further Search for Ketane and Acetic Acid Lines	A.H. Barrett	Mass. Inst. of Tech.	25	0	BARRETT-12XX
22.2-GHz Search for H ₂ O Emission From IR Stars	D.F. Dickinson	Smithsonian Astroph. Obs.	124	0	DICKINSON-10
22.2-GHz Further Search for H ₂ O Emission from Compact HII Regions	K.Y. Lo, B.F. Burke	Mass. Inst. of Tech.	48	0	BURKE-5X
16.038-GHz Search for Deuterated Formaldehyde	B.F. Burke, K.Y. Lo, D. Staelin, G. Papadopoulos	Mass. Inst. of Tech.	72	0	BURKE-6
7.6- to 8.4-GHz Further Search for Molecular Spectral Lines	B.E. Turner P.R. Schwartz, S. Mango J.H. Fertei	National Radio Ast. Obs. Naval Res. Lab. ---	200	0	SCHWARTZ-1X

TABLE II
PROGRAMS CONTINUED FROM PREVIOUS PERIOD

PROGRAM	INVESTIGATORS	INSTITUTIONS	Hrs. Used THIS Yr.	STATUS	DESIGNATION
8 & 15-GHz Monitoring of Quasars & Seyfert Galaxies	W.A. Dent	Univ. of Mass./Amherst	360	Continuing	DENT-1
7.85-GHz VLBI Observations with Goldstone 210-foot Antenna	T.A. Clark, G.E. Marandino R.M. Goldstein, D.J. Spitzmesser H.F. Hinteregger, C.A. Knight, A.R. Whitney, I.I. Shapiro	Univ. of Maryland Jet Propulsion Lab. Mass. Inst. of Tech.	82	Continuing	VLBI-9
7.85-GHz VLBI with Goldstone 210-foot Antenna	K.I. Kellerman, B.G. Clark J.J. Broderick, D.L. Jauncey M.H. Cohen, D. Schaffer	NRAO Cornell Calif. Inst. of Tech.	99	Continuing	VLBI-10
22.235-GHz H ₂ O Monitoring of Sources & Search for New Sources	J.A. Ball, D.F. Dickinson A.H. Barrett, K. Bechtis	Smithsonian Astroph. Obs. Mass. Inst. of Tech.	205	Complete/747	BARRETT-11
7.8-GHz Geodetic VLBI with Goldstone 210-foot and Alaska	I.I. Shapiro A.E.E. Rogers, S. Lippincott T.A. Clark D.J. Spitzmesser	Mass. Inst. of Tech. Haystack Obs. Goddard Space Flight Ctr. Jet Prop. Lab.	129	Continuing	VLBI-14
7.79-GHz Measurements of H 94 α in Planetary Nebulae	L.E. Goad, E.J. Chaisson	Harvard College Obs.	72	Complete/117	GOAD-2
1.6-GHz VLBI Measurements of Relative Positions of OH Sources with Algonquin Park	J.M. Moran J.G. Yen, P. Kronberg	Smithsonian Astroph. Obs. Univ. of Toronto	71	Complete/71	VLBI-16
8 & 15.5-GHz Continuum Search for Rapid Time Variation in Extragalactic Sources	E.E. Epstein	Aerospace Corp.	97	Continuing	EPSTEIN-1
16.56-GHz Measurements of H 73 α and He 73 α in Orion A.	G. Papadopoulos E.J. Chaisson	Mass. Inst. of Tech. Harvard College Obs.	0	Continuing	PAPADOPOULOS-3

TABLE II (Cont'd)

Page 2

PROGRAMS CONTINUED FROM PREVIOUS PERIOD

PROGRAM	INVESTIGATORS	INSTITUTIONS	Hrs. USED THIS Yr.	STATUS	DESIGNATION
22.235-GHz Measurements of Fluctuation Statistics in H ₂ O Emission from W49 (Cont'd)	J.M. Moran	Smithsonian Astroph. Obs.	19	Complete/19	MORAN-1X
22-GHz Continuum Measurements of Circular Polarization from the Sun During Eclipse of 10 July 1972	R.M. Straka	Boston Univ.	9	Complete/9	STRAKA-2
8.315-GHz Search for 92 α Recombination Transitions in Heavy Elements in W3 and Orion B	E.J. Chaisson	Harvard College Obs.	63	Complete/63	CHAISSON-9
8.315-GHz Measurement of 92 α Transitions in W51	E.J. Chaisson	Harvard College Obs.	129	Complete/129	CHAISSON-10
7.876-GHz & 8.372-GHz Search for Recombination Lines from C++ 149 α and 146 α	E.J. Chaisson	Harvard College Obs.	93	Complete/93	CHAISSON-11
8.315-GHz Search for (He 92 α) Recombination Line in HI Region Toward Orion B.	E.J. Chaisson	Harvard College Obs.	82	Complete/82	CHAISSON-12
15.5-GHz Continuum Search for Emission from Globular Clusters	J.M. Erkes, A.G.D. Philip	State Univ. of N.Y./Albany	33	Complete/33	PHILIP-1
22.235-GHz Measurements of H ₂ O Source Positions and Structure with Westford-Haystack Interferometer (Cont'd)	B.F. Burke, K.Y. Lo	Mass. Inst. of Tech.	291	Continuing	WESTACK-2X
60-GHz Line Profile Measurement of Atmospheric Emission (Cont'd)	J.W. Waters	Mass. Inst. of Tech.	40	Complete/40	WATERS-2X

TABLE II (Cont'd)

PROGRAMS CONTINUED FROM PREVIOUS PERIOD

Page 3

PROGRAM	INVESTIGATORS	INSTITUTIONS	HRS. USED		STATUS	DESIGNATION
			THIS	1/2 YR.		
7.8-GHz Radar Measurements of Lunar Topography with Westford-Haystack Interferometer	S.H. Zisk	Haystack Obs.	2		Complete	HAYMOON (Radar)
7.8-GHz Radar Measurements of Mercury & Venus Topography	R.P. Ingalls G.H. Pettengill	Haystack Obs. Mass. Inst. of Tech.	68		Continuing	MERCURY/VENUS TOPOGRAPHY (Radar)
7.8-GHz Radar Measurements of Venus Echo Spectra	R.P. Ingalls G.H. Pettengill	Haystack Obs. Mass. Inst. of Tech.	3		Complete/3	VENUS SPECTRA (Radar)
7.8-GHz Radar Measurements of Mercury and Venus - 4th Test of General Relativity	R.P. Ingalls G.H. Pettengill, I.I. Shapiro	Haystack Obs. Mass. Inst. of Tech.	65		Continuing	FOURTH TEST (Radar)
7.8-GHz Radar Measurements of Artificial Satellites at Synchronous Altitudes & Beyond	A.F. Pensa; Gp. 96 S.H. Zisk, R.P. Ingalls	MIT Lincoln Lab. Haystack Obs.	175		Continuing	LL-1 (Radar)
28 to 38-GHz Continuum Mapping Observations	G. T. Wrixon	Bell Telephone Labs.	0		Continuing	WRIXON-2
7.81-GHz Observations of C1186 Recombination Lines	E.J. Chaisson, A.K. Duoree	Harvard College Obs.	45		Continuing	DUPREE-2
22-GHz VLB1 Observations of H ₂ O Sources with NRAO 140-ft and NRL 85-ft antennas	G.D. Papadopoulos, B.F. Burke J.M. Moran K. Johnson, S. Knowles	Mass. Inst. of Tech. Smithsonian Astroph. Obs. Naval Research Lab.	128.5		Continuing	VLBI-15
24.9 to 25.1-GHz Observations of Methyl Alcohol Transitions (Cont'd)	A.H. Barrett, K. Bechis, R. Martin, K.Y. Lo	Mass. Inst. of Tech.	50		Complete/216	BARRETT-10X

II. Radio Astronomy - Selected Activities

A. Continuum Programs

Haystack Observations of the Cygnus X-3 Event

In early September, the X-ray source Cygnus X-3 exploded with an outburst of radio emission resulting in an unscheduled worldwide effort to observe the development of this event with whatever telescopes and equipment happened to be available. Haystack Observatory was fortunately able to make observations of several different kinds during the period 3 - 24 September when the enhanced radio emission was relatively intense. These observations were as follows:

- . The decay of the initial burst was monitored at 15.5 GHz over a period of five days until the flux dropped below 0.1 flux units. The observed decay of the first burst was found to be exponential as it decreased from an initial value of about 20 flux units. These observations were performed by investigators from the University of Massachusetts (Amherst), from Harvard College Observatory, and from the Smithsonian Astrophysical Observatory. The investigators interrupted their regular observing programs for these observations.
- . The second burst occurred during time scheduled for MIT investigators, who made both 15.5 and 22-GHz observations. To explain the spectral behavior with time, the model proposed for this activity pictured continual injection of relativistic electrons into a constantly expanding synchrotron source until the time of flare maximum.
- . The third sudden increase in radio flux occurred on 22-23 September, just as the VLBI group from MIT, University of Maryland, and NASA Goddard began a four-antenna experiment involving the Haystack and Westford antenna, together with two of the 85-ft antennas of the Green Bank interferometer. This group took advantage of this opportunity to observe Cygnus X-3 interferometrically on 24 September. No statistically significant fringes were obtained from Cyg X-3, allowing an upper limit of 1 F.U. to be placed on the unresolved flux; the total flux at that time was about 6 F.U. This gave an upper limit of about 0.01 arc seconds for the size of the source, if it is circularly symmetric.

Summarized by M. L. Meeks

A Survey of HII Regions with Large Infrared Excess

L. E. Goad - Harvard College Observatory

Recently an infrared survey of HII regions by J. Frogel and E. Persson of Harvard College Observatory has uncovered strong IR emission from many of the small diameter nebulae in the Sharpless catalogue (Ap. J. Suppl., 1959). These observations suggest the possibility that a number of the IR sources are compact HII regions similar to DR-21, for example. To detect such regions one must search at a wavelength sufficiently short for the nebulae to appear optically thin. Hence, a continuum search was undertaken at 7.8 GHz to measure the flux and position of radio emission from thirty-three nebulae with optical diameters less than eight arc minutes.

Although the data analysis is presently incomplete, it is clear that the continuum radio emission observed from these objects is smaller than expected. The most intense IR sources were barely detectable. Thus far, two radio sources have been found with emission in excess of 5 flux units.

B. Spectral Line Programs

Statistical Properties of Interstellar Maser Radiation

J. M. Moran - Smithsonian Astrophysical Observatory

Because of the high signal-level of the 22.2 GHz H₂O maser emission from W49, this source provides an opportunity to test the statistical properties of cosmic maser emission in the search for (1) deviations from gaussian statistics in the electric-field fluctuations and (2) correlations among amplitude fluctuations of the various features in the emission spectrum. In order to make these measurements it was necessary to interface the radiometer output with the CDC-3300 data-processing computer and to make use of some of the radar data processing arrangements. In the initial measurements of fluctuation statistics, a 16-KHz filter was centered on the most intense water-vapor feature in the W49 spectrum. The statistics of about 10^7 samples showed that the signal deviated from a gaussian distribution by no more than a few percent out to ± 4 standard deviations of the gaussian. However, since the feature-width was about 50 KHz, the sensitivity of the experiment was reduced by the narrowness of the filter. Observations were repeated with a 62 KHz filter and 8-microsecond sampling. These measurements showed no deviation from gaussian statistics to within one percent.

The search for correlations in 30-sec samples of the spectrum showed no significant correlations in feature fluctuations for time delays of three hours.

Correlations of Carbon Recombination Lines and OH Absorption Lines Toward Galactic HII Regions

E. J. Chaisson, Smithsonian Astrophysical Observatory

Radio recombination-lines due to carbon have been detected from relatively cool, predominantly neutral regions lying somewhere along the line of sight toward nine galactic nebulae. Narrow hydrogen recombination lines from four of these HI regions have recently been detected, and spectral features attributed to a superposition of magnesium, silicon, sulfur, and iron are seen in three cases. It now appears that certain absorption features of the hydroxyl radical OH, judging from similarity of radial velocities and linewidths, originate within these same regions.

The Haystack telescope and the 140-ft NRAO telescope in Green Bank, West Virginia, were used to observe respectively, C92 α (8.314 GHz) emission and 1.667-GHz OH absorption in the directions of W3A, W10, W12, W22, and W51A. For every carbon line detected, an OH absorption feature was found with very nearly the same radial velocity, although the converse was not true. A linear regression analysis of the similar C and OH radial velocities yielded a correlation coefficient of 0.9986.

A smaller positive correlation coefficient between the radial velocities of C92 α from HI regions and H92 α from HII regions within the nebulae suggests that the HI regions lie in the general vicinity of the nebulae. A strong correlation in the widths of the C and OH features was also found, with the carbon lines consistently showing a greater doppler spread. Evidently the carbon line originates in regions of greater turbulence or higher temperature, or both. In any case, these two components do not appear to be homogeneously mixed.

C. Interferometer Programs

Quasar Patrol¹

Very-long-baseline interferometry (VLBI) observations are made at 7.5 GHz with the "Goldstack" antenna combination (baseline $\approx 10^8$ wavelengths) on the average of once per month. This monitoring program, called the Quasar Patrol, is being carried out by two groups who observe alternately, under the rubrics VLBI 9 and VLBI 10 (See Table II). The goal is to study the remarkably rapid time variations in the fine structures of quasars and other compact extragalactic radio sources. About a dozen of these objects, including 3C84, 3C120, 3C273, 3C279, 3C345, 3C454.3, OJ287, OQ208, VR042.22.01, and 2134+00, are being followed regularly.

1. Goldstack VLBI Observations of Quasar Structure. See Haystack Semiannual Report of 15 July 1972, page 12.

The most exciting observations of the past few months revealed an intense outburst of radio radiation from 3C120 that started in early July. The increase in flux was unresolved by the interferometer in late August, but exhibited structure by early November (see Figure 1). If a single continuing outburst was responsible for the increasing flux, one is ineluctably led to the conclusion that the apparent expansion velocity of this event is about six times the speed of light. By assuming that two or more spatially separated, but nearly simultaneous, outbursts are involved one can avoid the spectre of apparent "super-relativistic" expansion. Of course, even if a single outburst is involved, one only requires expansion velocities, as measured at the source, to be nearly (not greater than) c to explain earth-based observations of apparent velocities in excess of c .

Precision Map of H₂O Emission from W3 (OH)

A new method has been developed to combine unambiguous fringe-rate data with ambiguous fringe-phase information to produce maps of the relative positions of various features in a given source of water-vapor emission. The method has been applied to W3 (OH) data obtained via VLBI on 28 March 1971 with Haystack, the NRAO 140-foot-diameter antenna at Green Bank, West Virginia, and the NRL 85-foot-diameter antenna at Maryland Point, Maryland. The map obtained from fringe-rate data alone is shown in Figure 2, while Figure 3 shows the equal-probability-density contours for the location of one feature (-51.2 km/sec) with respect to the reference (-48.8 km/sec), as determined from the addition of fringe-phase information.

Summarized by I.I. Shapiro

VLBI 15: H₂O VLBI Monitoring Program

B.F. Burke, K.Y. Lo, G.D. Papadopoulos; Mass. Inst. of Tech.

K.J. Johnston, S.H. Knowles; Naval Research Lab.

J.M. Moran; Smithsonian Astroph. Obs.

Emission from galactic clouds of water vapor was discovered in 1968. Shortly thereafter, the emission spectra were found to vary on the time scale of months. The spatial distributions of the emission features in the four sources W49N, ORION A, W3(OH) and VY Canis Majoris were measured in June 1970 with the very long baseline interferometer formed with the antennas of Haystack Observatory and the National Radio Astronomy Observatory (Green Bank 140', Kitt Peak 36'). The features in the first 3 sources were found to be spread over an area of dimension 10^{17} cm. The features in VY Canis Majoris were confined to 10^{15} cm indicating that the emission mechanism in this source is probably different from the other.

It was decided to undertake a monitoring program to measure the changes in the spatial structure of a small number of H₂O sources. Measurements

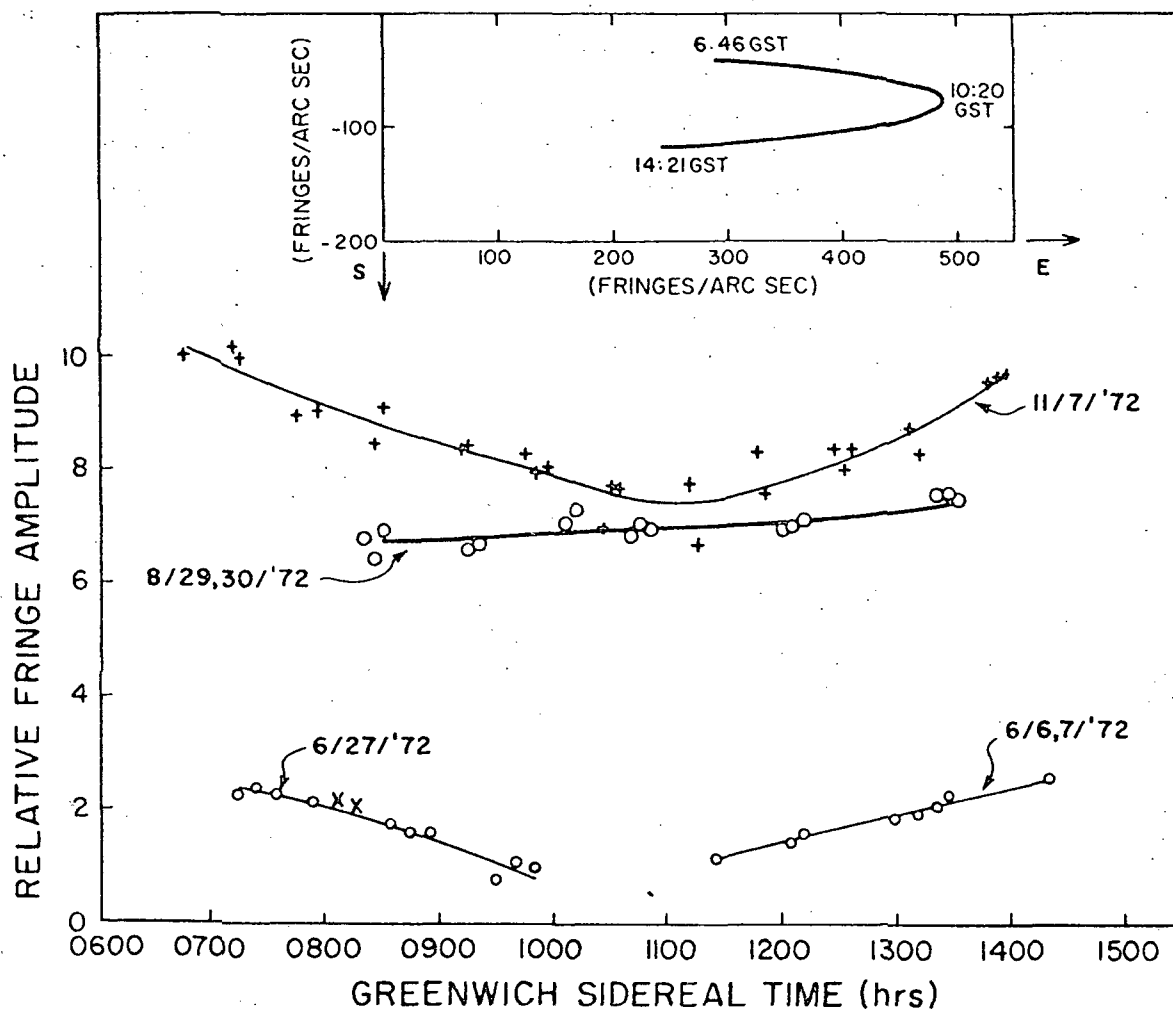


Fig. 1 Fringe amplitudes from observations of 3C120 made in 1972 with the Goldstone-Haystack interferometer. The inset shows the u-v plane coverage obtainable with this interferometer for observations of 3C120. The curves drawn through the data points are smooth representations of the latter and have no theoretical basis.

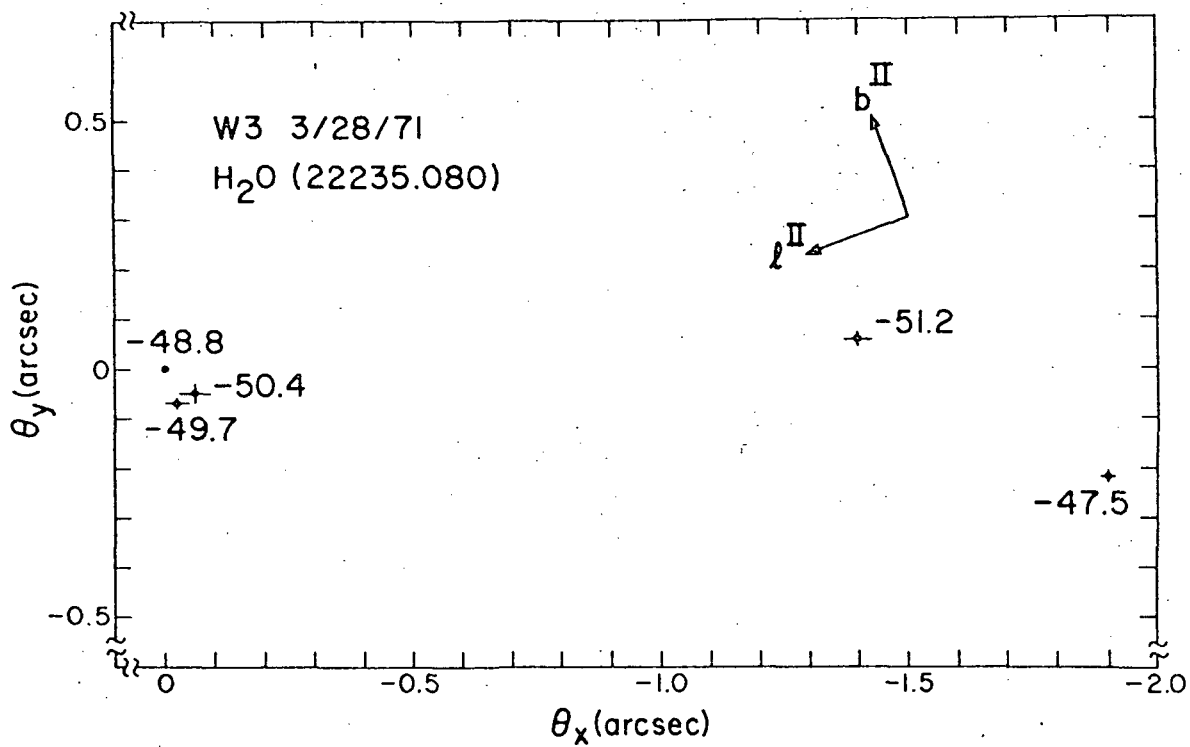


Fig. 2 Relative positions of water-vapor features in W3(OH) on 28 March 1971 as determined from 3-site VLBI determinations of fringe rates; see text.

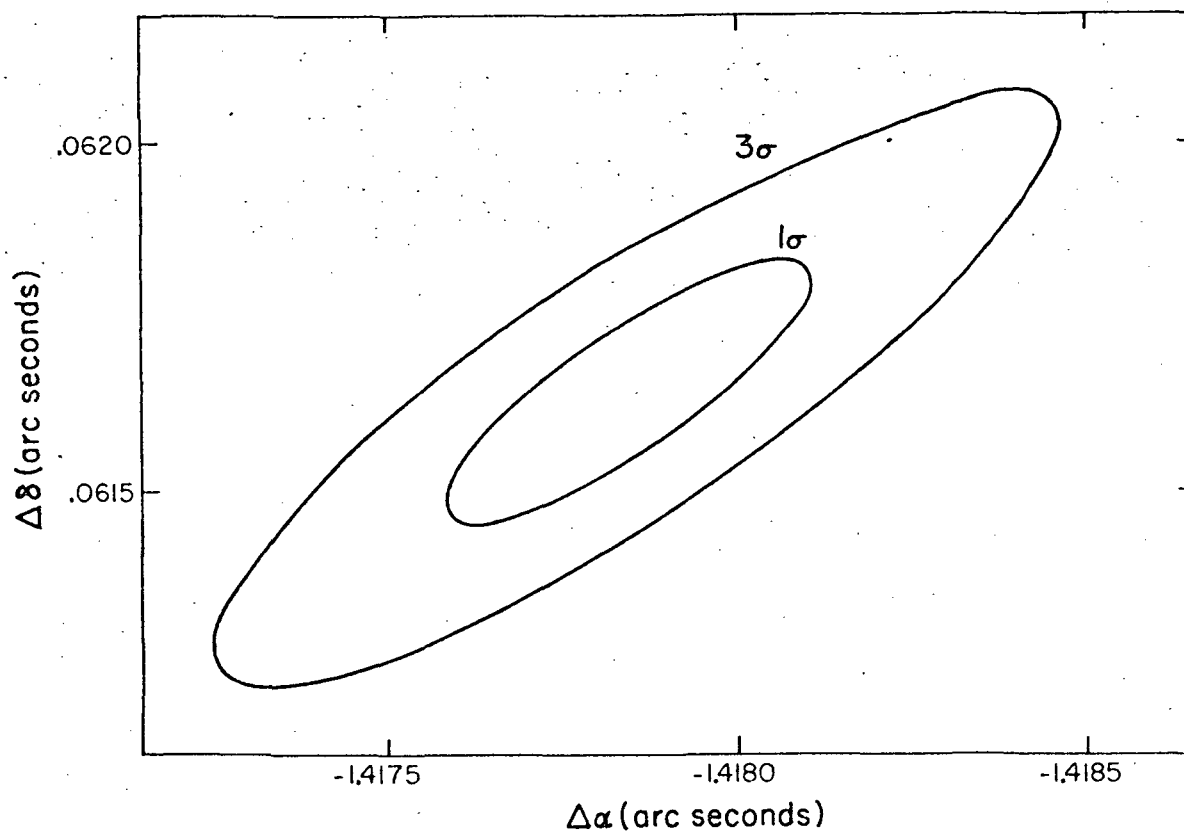


Fig. 3 Equal-probability-density contours for the location of the -51.2 km/sec water-vapor feature in W3 (OH) with respect to the -48.8 km/sec reference feature. These results are based on fringe-phase data obtained on 28 March 1971; see text.

were taken in February and March 1971 with the Mark I recording terminals. Measurements continued with the Mark II terminals in November 1971, May, September and December 1972. The data taken with the Mark II system are still being processed because of the long lead time necessary to develop new computer software.

In general we have found substantial changes in the spatial configurations of the emission features. In many cases, features have completely disappeared from a source's spectrum and new ones have appeared. The source W49N, for example, seems to have 3 active emission regions, and the features appear and disappear at random within these regions. Work on the interpretation of the time variations is continuing.

D. Geodetic VLBI Program

Observations of extragalactic radio sources from several 1972 Goldstone-Haystack VLBI experiments¹ were reduced to determine the values for the baseline vector and source positions. At the present stage of the analysis we find the baseline values determined from the various experiments to agree in length to on the order of 2 meters; the source positions agree in each coordinate in almost every case to within a few tenths of an arcsecond or less. Further analysis should yield the most accurate transcontinental geodetic data yet obtained and the most accurate relative positions for extragalactic radio sources.

A test experiment between Haystack and Onsala with a non-optimum configuration of the Onsala system yielded encouraging results; future experiments are expected to be sufficiently sensitive to provide a transatlantic geodetic tie with an uncertainty at the meter level.

Preliminary Reductions of Data to Determine Baselines of the North American Triangle

The VLBI data obtained in the spring of 1972 between Goldstone, California; Fairbanks, Alaska; and Tyngsboro, Massachusetts are being processed. To date, the California-Massachusetts data have received the major emphasis. These have been separated into four disjoint sets: April 14-15, June 3-6, June 27-28, and August 29-30. All of these sets have been reduced, except for several hundred tapes which were recorded on 9-track tape. Conversion to the 7-track form we require for processing, has been a stubborn practical problem that is now nearing solution.

-
1. A rather complete description of these experiments, including the background, experimental approach, and equipment, begins on page 13 of the Haystack Semiannual Report of 15 July 1972.

Preliminary baseline vectors, source positions, and clock offsets were determined from the data already reduced using VLBI-3¹. Examination of the postfit residuals and intercomparison of the results indicate that some systematic effects have not yet been adequately accounted for. As a result, the relative phase calibration of the signals from each of the frequency "windows" has been re-examined and an improved result is expected from reprocessing through VLBI-2¹. In addition, successive observations on the same source have been reprocessed coherently, so as to improve the precision in the fringe-rate determinations. This will improve the estimates of the source positions and the equatorial components of the baseline vector.

Our present results, prior to the incorporation of these improvements and of the remaining data, show for the four disjoint Haystack-Goldstone data sets a spread in the estimates of the equatorial baseline components of about 2 m and in the estimates of the polar components of about twice that. The source position estimates indicate agreement to within several tenths of an arc second in both coordinates for sources observed in common in several of the observation periods.

"Phase Connection" of Triplet Sets

Many of the observations taken between Haystack and Goldstone consisted of triplets. That is, three three-minute runs were taken five minutes apart on the same source. Coherent processing of these runs allows the delay rate to be determined with much higher precision since the coherent integration spans 13 minutes. In addition, the increased coherent integration improves the delay determination by $\sqrt{3}$.

An example of a coherently processed triplet of three minute runs is shown in Figure 4. Although the residual phase-delay is constant to within plus or minus 10 picoseconds -- or light equivalent of plus or minus 3 millimeters, each triplet requires a separate "clock offset" term unless further phase correction can be performed.

A.E.E. Rogers
I. I. Shapiro

E. Radiometric Instrumentation

1. K-band Maser Development

For the past two years a helium-cooled maser amplifier designed to cover both the H₂O vapor line at 22.2 GHz and one or more of the ammonia lines beginning at 23.7 GHz, has been under development at Haystack and University of Massachusetts. U. Mass., Harvard and MIT are each contributing support toward this development. Credit is also due MIT Lincoln Laboratory for engineering consultation and for the use of specialized capabilities in gold plating of the ruby and other components.

1. VLBI-1, 2 & 3 are computer programs for processing VLBI data. VLBI 1 correlates the data; VLBI-2 derives fringe rates and delays; VLBI-3 estimates source position, baseline and clock parameters.

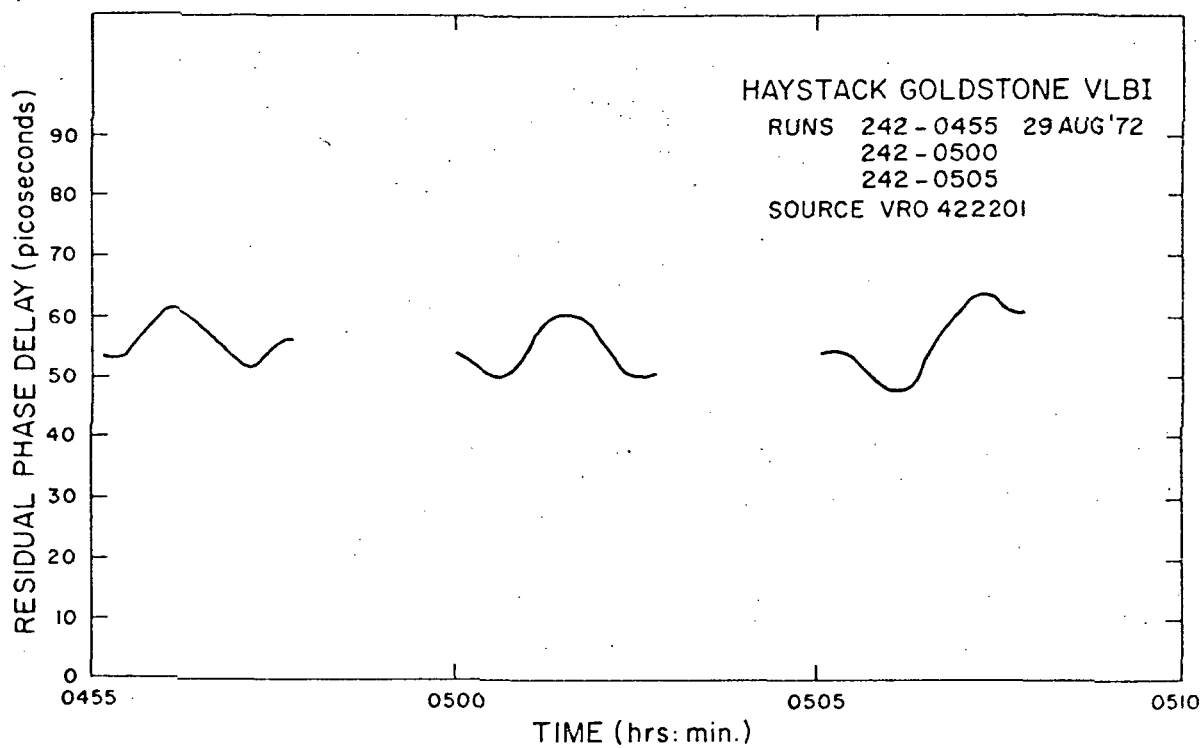


Fig. 4 Phase Connection of Three Adjacent VLBI Observations. The zero level of the phase delay axis is arbitrary.

The maser has now been successfully completed. Bench tests at U. Mass. show a gain of from 30 db at water-vapor to 40 db at ammonia frequencies, with a bandwidth of 12-18 MHz. For ammonia, where a wider instantaneous bandwidth is desirable, the maser has been readjusted for a wider bandwidth of 25-30 MHz, with a gain of better than 30 db. The essential parts of the system are now back at the Observatory, where they will be installed in the Radiometer Box in late January 1973 for the first overall system tests on the antenna.

A new K-band waveguide switching system has been designed and installed in the R-box in preparation for the maser. Operating modes are provided to cover most types of continuum, spectral line, and interferometer observations. Total power observations will be possible with either horizontal or vertical linear polarization, or right or left circular polarization. Dicke-switched observations are provided for, with either a room temperature load, an offset feed, or an orthogonal polarization as the comparison signal source. The system can also by-pass the maser so as to use just the mixer for any observations between 19 GHz and 25 GHz which fall outside the tuning range of the maser.

S. Yngvesson	J.C. Carter
D. Desmond	J.M. Sobolewski
A.G. Cardasmenos	S.H. Zisk
(Univ. of Mass.)	(Haystack Obs.)

C.E. Hurwitz
L.P. Rainville
(MIT Lincoln Lab.)

2. Other K-band Developments

The mixer used for 22-25 GHz observations also works well down to 19 GHz, but a new oscillator system had to be built to cover this lower range. It uses a klystron, phase-locked to a harmonic of approximately 1,500 MHz, which, in turn, is produced by a transistor oscillator, phase-locked to a harmonic of a control room frequency synthesizer.

We find that dual phase locked loops like this one work very well for spectral line radiometer local oscillators and, in fact, have used this technique to lock LO klystrons at frequencies up to 42 GHz.

A new phase-locked oscillator system was also installed on the Westford antenna to provide a local oscillator suitable for K-band interferometry operations. The earlier system, which used parts of the 8-GHz local oscillator, was difficult to set-up, very difficult to service, and had inadequate tuning ranges.

J. C. Carter

3. X-band Cooled Parametric Amplifier

The 15 July 1972 Semiannual mentions briefly the addition early in the year of a Comtech cryogenically-cooled X-band parametric amplifier to the Haystack instrumentation. It can be used with either the Radiometer Box or the Planetary Radar Box on the antenna. Some of the operating characteristics are given below:

Tuning Range	7.6 - 8.5 GHz
3 db Bandwidth	100 - 200 MHz
Noise Temperature	$\approx 35^\circ\text{K}$ @ 7850 MHz
Gain Stability, for periods ≤ 1000 sec.	< 0.05 db, peak-to-peak

As an operating receiver front end this paramp serves the Observatory well. It is used for spectral line, continuum, VLBI, and most radar operations. Its greatly increased bandwidth and tuning range, as compared to the traveling-wave maser in the PR Box, have made possible improved VLBI measurements, observations of many more recombination lines, and searches for a number of new molecular transitions. Furthermore, the availability of this system with either "Box", together with the elimination of liquid helium fills of the maser, permits more efficient and flexible scheduling of X-band operations, whether radio astronomy or radar. We are pleased also to report that, between 6000 hour overhauls, the cryogenic system requires little attention beyond the addition of a little helium at box-change times to compensate for losses incurred when helium-lines are broken and re-connected.

We have obtained considerable data on the actual system noise temperature vs. elevation angle, during some 12 VLBI observations which ran from 16 to 24 hours each. The results are shown in Figure 5. Data obtained during bad weather have been eliminated. The higher zenith temperature using the P/R-box is due to the long waveguide run made necessary by the requirement (for space reasons) that the paramp antenna unit be kept outside the Planetary Radar Box. We hope to be able to reduce this length somewhat, and possibly to go to oversize waveguide. The rapid increase in temperature at lower elevation angles using the R-box is due to scattering of ground radiation from the external polarizer which is required in front of the feed to obtain left circular polarization for the VLBI setup. Without the polarizer the zenith temperature is about 3° lower than shown, and the curve maintains the same shape as the P/R-box curve. For Dicke switched continuum measurements the overall system temperature is $35 - 45^\circ\text{K}$ higher than shown due to losses in the ferrite switch and additional required waveguide.

S. Lippincott
J. C. Carter

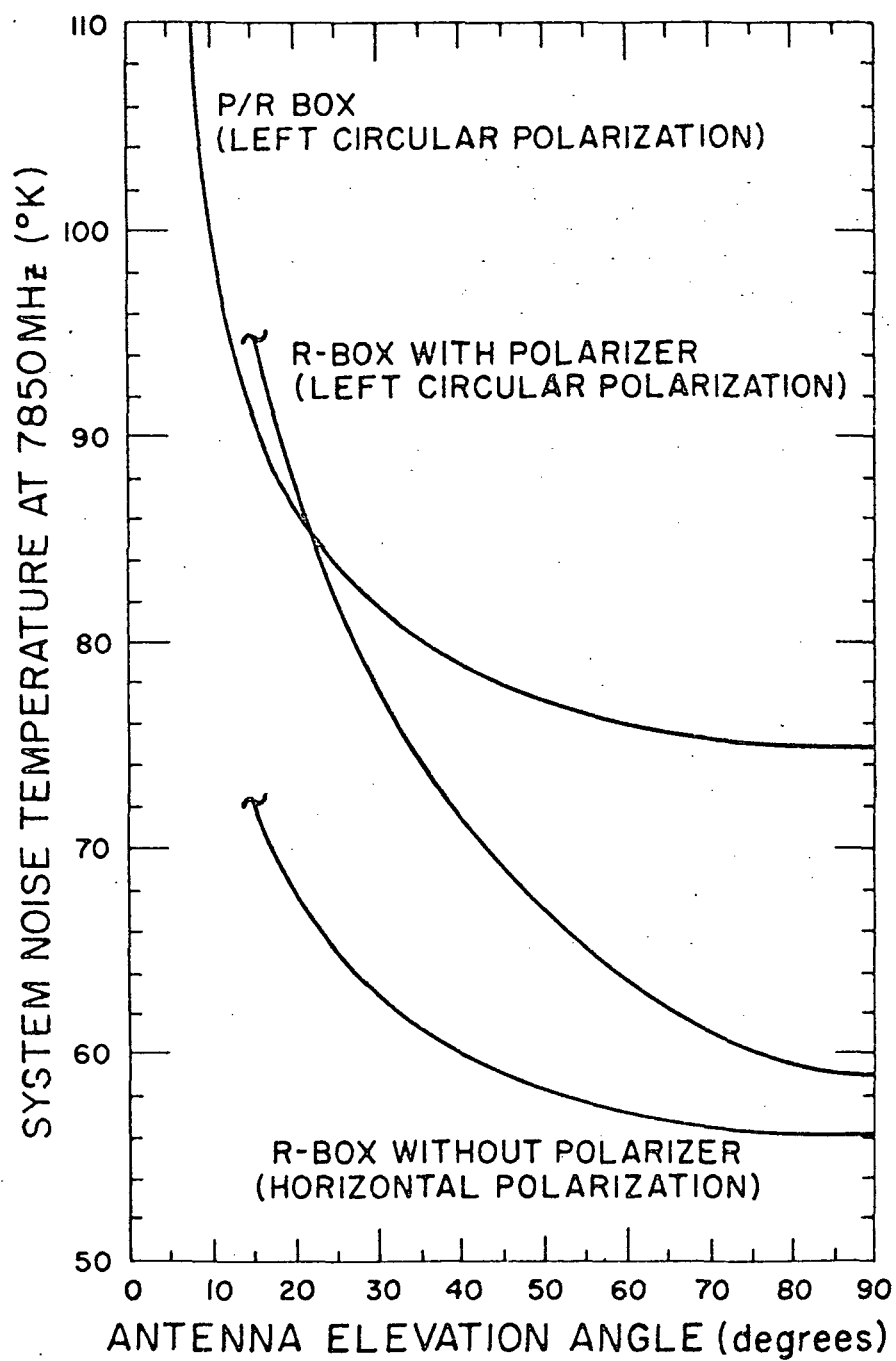


Fig. 5 System Noise Temperature with paramp at 7.85 GHz.

4. Spectral Line Digital Correlator

A 1024-channel digital correlator is being designed at Haystack Observatory for use in spectral line research. The new system will replace the present 100-channel unit, which accommodates a maximum bandwidth of 20 MHz.

As shown in Figure 6, the spectral line system will be composed of four subsystems:

- The Correlator Control will sequence all real time operations such as signal sampling, multiplexing, correlator readout, data summation, etc. Initially, the Fourier transform will also be done in the control computer.
- The Correlator proper will be organized as sixteen 64-channel sections with two additional spares. This organization, along with the Signal Conditioning system, allows a direct trade of channels for bandwidth. Preliminary specifications are:

1,024 Channels @ 10 MHz Bandwidth
512 " " 20 " "
256 " " 40 " "

- High speed sampling and data switching are provided by the Signal Conditioning system. This feature is required for the higher bandwidths as well as for planned automatic test routines.
- The Display Control and its display provide for an on-line interface to the Observer. It accepts and displays the transformed data under operator control, and communicates with the pointing computer. Eventually, as the spectral line system is expanded, the transform will be performed in the display control itself.

Both of the above-mentioned control computers have been delivered, and are being checked out, so that software design for these machines can proceed concurrently with the hardware designs for the other subsystems.

It is estimated that checkout of the completed device can take place early in 1974.

J. I. Levine

5. Dew Point Monitors

The dew points of the air both inside and outside the radome can now be monitored at the main control console. Outside dew point is required by the U490 computer to make the antenna pointing refraction correction. Until now, the observer has had to go outdoors and measure the dew point with wet and dry bulb thermometers. This time consuming process was done too infrequently.

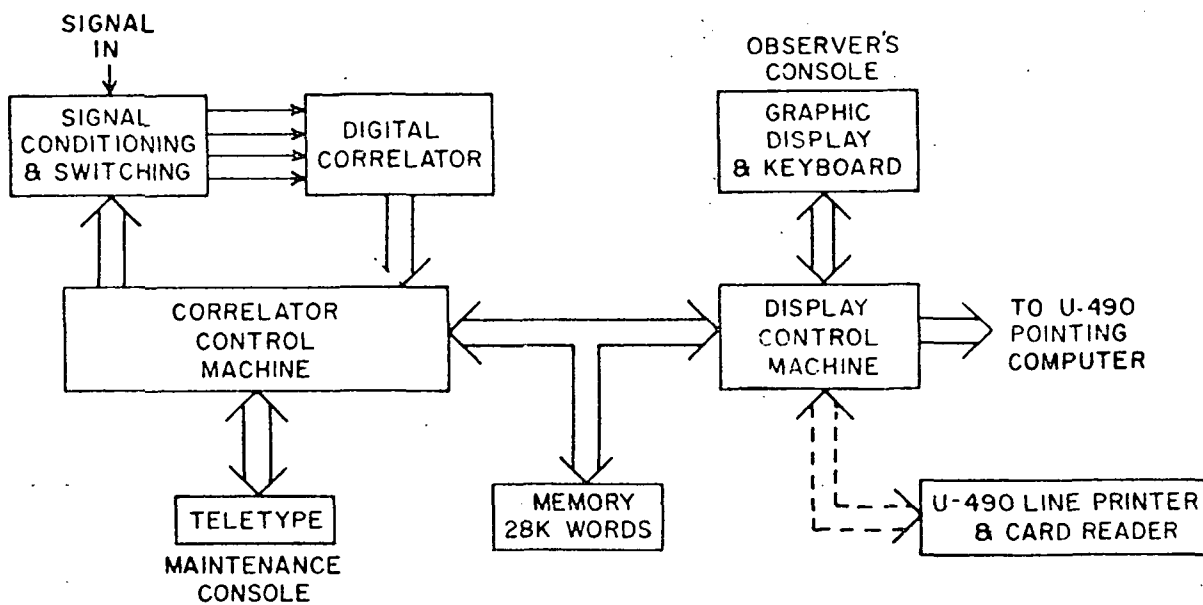


Fig. 6 1024-Channel Spectral Line Correlator System.

Increased operation of Haystack at higher frequencies, and, therefore, narrower beamwidths, requires more frequent dew point measurements, which are easily obtained with the new monitor.

Knowing the dew point inside the radome helps the observer determine the chances of water condensation on the inside radome surface.

6. Phaselock Receiver for Maser Frequency Standard

Under the ARPA/ACIC contract, we have ordered from Smithsonian Astrophysical Observatory an atomic hydrogen maser oscillator frequency standard to be used both as a portable standard for VLBI and as a second standard at Haystack when not required at remote observing sites. This oscillator puts out a weak L-band signal of about -100 dbm level, at a frequency of 1,420,405,751.768 Hz. For frequency standard applications, the maser output signal, which has excellent long term stability but poor short term stability, is used as the reference input to a phase locked loop, which controls a 5 MHz quartz crystal oscillator. This arrangement, properly engineered, affords both good short-term and good long-term stability. The function of the phaselock receiver being developed at Haystack is to provide the interface between the two oscillators, so that the maser controls the quartz oscillator at an optimum bandwidth.

The phaselock receiver consists of five sections: local oscillator, signal, baseband, monitor, and power. The local oscillator section has been designed to provide injection frequencies derived from the 5 MHz oscillator for the various signal mixers with the best short and long term phase stability which can be achieved. The signal section amplifies and limits the bandwidth of the low level signal from the maser, and converts its frequency to a convenient value for phase detection. The baseband section integrates the phase detected signal, amplifies it, offsets its DC level and applies its output to the frequency control input of the 5 MHz quartz crystal oscillator, thereby completing the phase lock loop. The monitor section provides status and monitor indications and outputs for recorders for the various critical functions in the receiver. The power section provides clean regulated power for the receiver and all its related equipment, and for the maser itself. This power system is designed to provide uninterrupted operation from 100 to 250 volts 50 to 400 Hz A.C. lines, 24 volt lead-acid batteries external to the equipment, and from 24 volt nickel-cadmium batteries within the equipment, so that power interruptions or short term transportation will not disrupt the continuity and stability of the output signal.

In most sections, designs are nearing completion and procurements and construction are underway. Completion and test are forecast for April, 1973.

S. Lippincott

III. RADAR PROGRAMS

A. Moon

The lunar topography measurement program that was begun in 1970 was concluded with a series of high-resolution contiguous (in time and lunar surface coverage) measurements of individual maria, large craters, and distinct terra formations.

Examination* of earlier measurements revealed evidence for relatively recent volcanic flows in parts of a large region including the craters Alphonsus and Arzachel. A lava flow with relatively high viscosity may have issued from crustal fractures resulting from the Imbrium impact event. This hypothesis is based on the radar-observed topographic sculpturing of the above-mentioned crater floors, including the alignment of their central ridges with a long crater chain radial to Mare Imbrium.

Troublesome inconsistencies observed earlier between the measurements and the lunar ephemeris now appear to have been mostly resolved through the adaptation of the lunar predictions of the Lincoln Laboratory/MIT Planetary Ephemeris Program to the reduction of the multi-point Haystack radar maps. This happy result should produce maps of lunar features with a positional accuracy of 2 km or better, as well as pointing the way to a global map of absolute elevations with better than 1 km precision from radar results alone. The potential exists for even better precision through comparison with the Apollo orbital laser altimeter results.

Further analysis is also under way of the earlier 1968-69 surface radar-backscatter data. Comparison with surface characteristics measured on the Apollo missions may improve our understanding of the mechanism of planetary surface radar backscattering, but at this time the Apollo results are still being studied.

A completion report is in preparation on the lunar topography work under Contract NAS9-7830.

S. H. Zisk

* Lunar Topography: First Radar-Interferometer Measurements of the Alphonsus-Ptolemaeus-Arzachel Region, S.H. Zisk, Science Vol. 178, December 1972

B. Mars

Activities under this program were confined to consideration of broad plans for a long series of observations centered on the October 1973 opposition of Mars and emphasizing careful range measurements for topographical purposes. The series is scheduled to begin in mid-summer.

G.H. Pettengill
A.E.E. Rogers

C. Mercury

A further series of topographic ranging observations were performed near the inferior conjunction of 7 August 1972. As with the March-April Observations, a height accuracy of better than 1 km was obtained, with a longitude resolution of about a degree. These topographic measurements will be useful for removing the effects of planetary topography from orbital determinations, as well as of interest in their own right.

Range delay measurements emphasizing orbital coverage away from conjunction were made during November, starting near east elongation on 5 November. In the past, coverage of Mercury has emphasized work near inferior or superior conjunction, resulting in a lack of data covering the elongation periods.

R. P. Ingalls

D. Venus

A continuation of Venus topographic ranging observations occupied the period of late July and August. Both a standard 24 microsecond pulse width and a finer grain 10 microsecond pulse were used during these measurements. These data, along with other observations taken nearer the 17 June 1972 inferior conjunction, are being analyzed, together with Arecibo Observatory Venus ranging observations from the same time period, to build up an extensive picture of Venus topography. An initial presentation of the 24 microsecond Haystack results from this period is given in Figure 7. During November only a small number of Venus ranging observations were made, as the emphasis was placed on the analysis of topographic data from 1972, rather than upon additional coverage of the planet as it approaches superior conjunction in April 1973.

R. P. Ingalls

E. Satellite Observations

The highlight of this period's data reduction effort at MIT Lincoln Laboratory was the completion of the analysis of the data obtained at Haystack

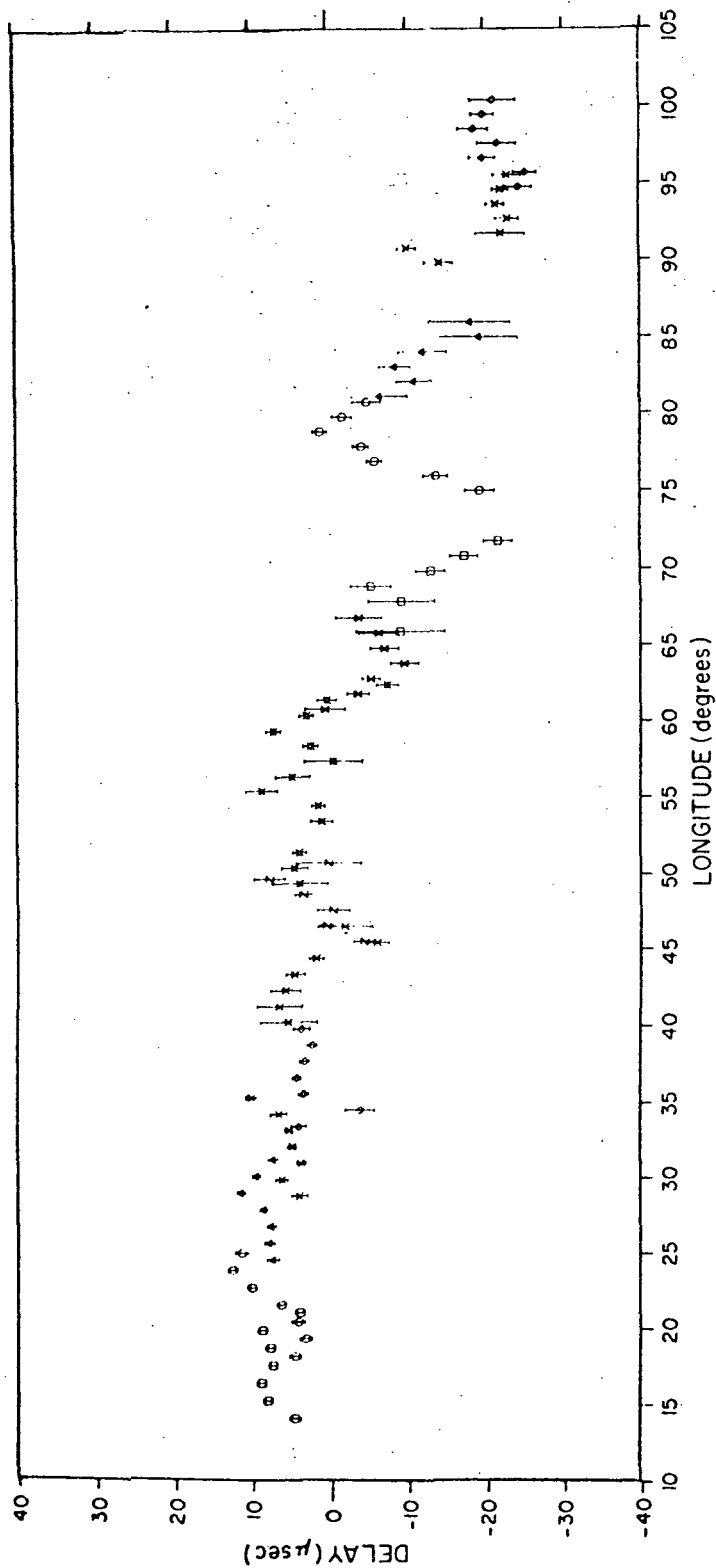


Fig. 7 Venus topographic delay results from 26 July through 30 August 1972. Range delay to the planetary surface, with orbital delay removed, is plotted as a function of longitude on the planet. Coverage over a band in longitude is obtained by frequency resolution within a particular daily observation, as indicated by symbol change for each of the 15 observations. The highly elevated region near 100° Longitude is evident from the large negative delay residuals.

during the cooperative experiment described in the 15 July 1972 Semiannual report, in which the radar observed controlled movements of antennae on a synchronous satellite. The data analysis revealed a great deal of information in the phase component of the received quadrature video signal. By using the received phase with the residual ephemeris phase removed, it is possible to measure range changes on the order of a few millimeters. Precise measurements of velocity increments applied to the satellite along the radar line of sight can also be made.

Observations during this period were mainly concerned with increasing the data base size for several targets which we have been tracking on a regular basis. A successful search for LES-6 was conducted in August and vividly demonstrated the capabilities of our real time spectral display as an acquisition aid. In early November this same technique was used to acquire Intelsat 2 F-4, the smallest synchronous target seen by Haystack.

A.F. Pensa et al, Lincoln Laboratory
R.P. Ingalls
S.H. Zisk

F. Radar Instrumentation

The radar system continued using VA-949BM klystrons S/N 22 and S/N 25 operating conservatively at a maximum of 300 kw CW. The Comtech paramp was used for most radar receiver operations, with the X-band Maser being put into service only for high sensitivity observations. The major waveguide modifications required for including the Comtech paramp in the PR Box had been completed during the last report period. The corresponding upgraded control panel system for controlling waveguide switches and other equipment is now installed and was partially checked out at the end of December.

Several significant operational improvements were added to the satellite radar configuration. A new Sanborn chart recorder was installed in a console desk section next to the antenna console for monitoring several signals during satellite operations of the radar. This chart recorder (which is identical to the existing "radiometer" recorder) may also be used to record any signals available at the radiometer distribution system, such as azimuth servo error or a detected satellite beacon signal received at Westford, or as an alternate to the regular "radiometer" recorder.

A special "Satellite" bootstrap tape was made for the U490 pointing computer that simplified satellite orbital parameter initialization by eliminating unused features of the normal bootstrap. A provision was made to "tag" the current position of the antenna using the U490 Offset Entry system. When the appropriate push button is operated, the typewriter gives the position of the antenna beam relative to the predicted orbit. This feature is useful in an acquisition search operation, in that the angular position of a "hit", relative to predicted position, may be easily regained after clearing the search scan from the orbital pointing.

A remote CRT for the CDC 3300 display was added to the new console. This is of significant assistance in satellite searches as it provides a real-time display of signal spectra at the operator's console. The addition of an audible alarm threshold detector to sense a "spike" on the display input signal eliminated hours of glueing eyeballs to the CRT display. Since the display noise level is constrained in amplitude, a "spike" on the spectral display signifies a hit on the satellite target.

A number of software modifications have been made to the real time satellite dual channel spectral program in the CDC-3300, designed to aid in the use of the CRT display. The display now continually updates output spectra during a run or search and is normally refreshed with a new spectrum every 2 seconds. The display is scaled at low signal to produce a noise amplitude in the spectrum of about 20% of full scale. For high signals the plot is scaled to the peak value of the signal spectrum, overriding the noise scaling. The operator can choose to record on magnetic tape time samples of signal data from two channels. These normally would be two-level or two-polarization radar data, or, in the case of simultaneous beacon observations at Westford, a single radar signal plus the beacon signal.

There are currently two basic operating modes for satellite observations. The search, or acquisition, mode uses 0.2 second pulses and 0.5 second repetition period. Since most of the observed synchronous or near synchronous satellites have round trip flight times of about 0.26 seconds, there is no necessity for range tracking in this virtually CW mode. Coherent processing is done within the single pulse, and incoherent sum spectra of about 2 seconds integration time are displayed for the operator. For satellites whose orbit is not precisely known (within a beamwidth or so in position), a box or raster scan is set up about the predicted center by the U490 SCAN program. Generally, areas of the order of 1° to 2° square are searched with a scan which allows several hits as the beam scans across the target position. When a "hit" is observed and the offset in pointing "tagged", the box scan is removed and the antenna offset by handwheel from the predicted position to locate the target. It has been possible, for virtually all cases experienced, to follow the target under computer control for better than 15 minutes without correction, even for targets located a degree from predicted position.

Most of the significant signal analysis is performed on data taken in a more typical pulse radar configuration in which, however, only one range box is measured, and the target flight time is some 40 repetition periods in delay. The pulse width is 2 milliseconds and a typical repetition period is 6.25 milliseconds. The repetition period must be adjusted so that the target echo is not lost beneath the transmitted pulse. The echo motion for some faster targets restricts run lengths to only about 5 minutes before the radar repetition period needs adjustment. A device to perform this task automatically is underway.

Doppler frequency tuning is performed by the existing radar receiver tuning equipment, using the predicted orbit in the U490 as a basis for determining range rate. A fixed offset is used to make a fine trim. We have found that virtually all of the echo frequency errors experienced were well within the 1.25 KHz bandpass processed by the CDC-3300 in the search mode.

R.P. Ingalls
R.A. Brockelman

APPENDIX

Publications for July - December 1972

- (R) Infrared and Radar Maps of the Lunar Equatorial Region
R.W. Shorthill, T.W. Thompson, S.H. Zisk
The Moon, Vol. 4, Nos. 3/4, June/July 1972
- (R) A New, Earth-Based Radar Technique for the Measurement of
Lunar Topography
S. H. Zisk
The Moon, Vol. 4, Nos. 3/4, June/July 1972
- Evidence for Spatially Independent Outbursts in Compact Radio Sources
W. A. Dent
The Astrophys. Jnl., 175-L55-L58, July 15, 1972
- An Attempt to detect the 3-cm Fine-Structure Transition of
Hydrogen in HII Regions
P.C. Myers, A.H. Barrett
The Astrophys. Jnl., 176, 111-126, August 15, 1972
- (R) Calibration of Radar Data from Apollo 16 Results
S.H. Zisk, H.J. Moore
Apollo 16 Preliminary Science Report
(In Press)
- Interferometric Observations of an Artificial Satellite
R.A. Preston, R. Ergas, H.F. Hinteregger, C.A. Knight,
D.S. Robertson, I.I. Shapiro, A.R. Whitney
Science, Vol. 178, No. 4059, October 1972
- A Flux Density Scale for Microwave Frequencies
W.A. Dent
Astrophys. Jnl., Vol. 177, No. 1, Part 1, October 1972
- (R) Venus: Radar Determination of Gravity Potential
I.I. Shapiro, G.H. Pettengill, A.E.E. Rogers, R.P. Ingalls
Science (In Press)
- Precision Geodesy via Radio Interferometry
H.F. Hinteregger, R. Ergas, C.A. Knight, D.S. Robertson,
I.I. Shapiro, A.R. Whitney, T.A. Clark
Science, Vol. 178, No. 4059, October 1972
- (R) Lunar Black Spots and Nature of the Apollo 17 Landing Area
C. Pieters, T.B. McCord, S.H. Zisk, John B. Adams
Jnl. of Geophys. Research
Publ. #72 of Planetary Astr. Lab., November 1972
-
- (R) Radar Related Research

Detection of the 4_1-3_0 (E_2) Line of Interstellar Methyl Alcohol
B.E. Turner, M.A. Gordon, and G.T. Wrixon
The Astrophys. Jnl., November 1972, Vol. 177

- (R) Lunar Topography: Global Determination by Radar
I.I. Shapiro, S.H. Zisk, A.E.E. Rogers, M.A. Slade
and T.W. Thompson
Science, Vol. 178, No. 4064, December 1972

Observations of Radio-Recombination Lines in Planetary Nebulae
L.E. Goad, E.J. Chaisson
Proc. of the 18th International Liege (Belgium)
Symposium, 1972

Some Characteristics of an Operational System for Measuring
UT-1 Using Very Long Baseline Interferometry
J.M. Moran
Space Research, Vol. XIII, 1972

- (R) Lunar Topography: First Radar-Interferometer Measurements of
the Alphonsus-Ptolemaeus-Arzachel Region
S.H. Zisk
Science, Vol. 178, No. 4064, December 1972

High Resolution Observations of the Chromosphere at MM
and CM Wavelengths
M. Simon
Solar Physics (In Press)

Detection of Cyanoacetylene at 18 GHz
D.F. Dickinson
Astrophys. Letters, Vol 12, #4, December 1972

7.8 GHz Flux Density Measurements of Variable Radio Sources
W.A. Dent, G. Kojoian
Astronom. Jnl. (Scheduled - December 1972)

- (R) Lunar Surface Topography: Computer Generation and Display
of High-Resolution Radar Astronomy Maps
S. H. Zisk
Astronomy and Astrophysics, (In Press)

- (R) Apollo 16 Landing Site: Summary of Earth-Based Remote
Sensing Data
S.H. Zisk, H. Masurski, D.J. Milton, G.G. Schaber,
R.W. Shorthill, T.W. Thompson
Apollo 16 Preliminary Science Report (In Press)

- (R) Radar Mapping of Lunar Surface Roughness
T.W. Thompson, S.H. Zisk
AIAA Progress Series Volume, "Lunar Thermal Characteristics
of the Moon", J.W. Lucas, Ed., MIT Press, Vol. 28, 1972